



UNIVERSITI PUTRA MALAYSIA

**COMPARATIVE EFFICACY OF VARIOUS SOURCES
AND RATES OF PHOSPHATE ROCKS
TO OIL PALM SEEDLINGS**

MUHAMMAD EDWIN SYAHPUTRA LUBIS

FP 1997 10



**COMPARATIVE EFFICACY OF VARIOUS SOURCES
AND RATES OF PHOSPHATE ROCKS
TO OIL PALM SEEDLINGS**

By

MUHAMMAD EDWIN SYAHPUTRA LUBIS

**Thesis Submitted in Fulfilment of the Requirements for
the Degree of Master of Agricultural Science
in the Faculty of Agriculture,
Universiti Putra Malaysia.**

June 1997



Dedicated to my parents



ACKNOWLEDGEMENTS

I wish to express my sincerest appreciation to Associate Prof. Dr. Zaharah A. Rahman for her generous and valuable contribution as the Chairman of the Supervisory Committee during the course of this work.

Special appreciation is also extended to Prof. Hj. Sharifuddin Abd Hamid and Dr. Rosenani Abu Bakar, member of this Supervisory Committee for their suggestions and comments.

Special thanks also go to everyone in my family, especially my father and mother, for their endless love, encouragement and support throughout the course of this study.

Gratitude is also expressed to god, for blessing me, affording me the opportunity and for keeping me healthy to undertake this study.

Last, but not least, my special thanks to all those who have provided assistance and encouragement to make this work a success.



TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	x
LIST OF ABBREVIATIONS	xi
ABSTRACT	xiii
ABSTRAK	xvii
 CHAPTER	
I INTRODUCTION	1
II REVIEW OF LITERATURE	5
Forms of Phosphorus in the Soil	5
Factors Affecting P in the Soil and Uptake by Plant	7
Mechanisms of P Supply to Plant Roots Growing in the Soil ..	11
Phosphorus Functions in the Plants	12
Effect of P Deficiency	14
Phosphorus in Oil Palm	16
Phosphorus Functions in Oil Palm	17
Phosphorus Requirement in Oil Palm	18
Phosphorus Deficiency in Oil Palm.....	19
Sources of Phosphate Fertilizer	20
Direct Application of PR as a Source of P Fertilizer	20
Chemical and Mineralogical Characteristics of PR	23
Factors Affecting the Agronomic Effectiveness of PR for Direct Application	26
Sources of PR	27
Soil Properties	30
Management Practices	33
Crop Species	34
Methods of Evaluation of PR for Direct Application	34
Chemical Method	35
Physical Method	36
Agronomic Method	36



	Assessment of Bioavailability of P Using Isotopically Exchange Method	37
	Principle of ³² P Isotop Method (E value)	38
III	COMPARISON OF VARIOUS PR SOLUBILITY TESTS AND THE RELATIVE AGRONOMIC EFFECTIVENESS OF PRs USING OIL PALM SEEDLINGS IN A GLASSHOUSE EXPERIMENT	
	Introduction	40
	Materials and Methods	42
	Characterization of PR	42
	PR Solubility Test	42
	Glasshouse Experiment	43
	Parameters	46
	Results and Discussion	48
	PR Solubility Test	48
	Glasshouse Experiment.....	58
	Soil Properties	58
	Effect of PR on Soil Chemical Properties	58
	Diameter of Trunk	71
	Total Dry Matter Yield	73
	Plant P Uptake	77
	Relative Agronomic Effectiveness	83
	Conclusions	87
IV	DISSOLUTION OF PR IN AN ACID SOIL (INCUBATION STUDY)	
	Introduction	89
	Materials and Methods	91
	Results and Discussion	92
	Soil pH	92
	Extractable P	96
	Exchangeable Cations	100
	Dissolution of PRs	103
	Conclusions	106



V	ASSESSMENT OF BIOAVAILABILITY OF P USING ISOTOPIC EXCHANGE KINETIC LABORATORY EXPERIMENT (E VALUE)	
	Introduction	108
	Materials and Methods	110
	Determination of Isotopically Exchangeable P	111
	Determination of P in the Soil Solution (Cp)	112
	Determination of P Status and Kinetics Parameters	112
	Calculation of P Derived from Fertilizer (% Pdf)	116
	Determination of Relative Agronomic Effectiveness	117
	Analysis of Data	117
	Results and Discussion	118
	Soil P Status Parameter	118
	The Relationships between Plant P Uptake and E Value ...	132
	Relative Agronomic Effectiveness	132
	Correlation between the E value and P Uptake	135
	Conclusions	138
VI	SUMMARY AND CONCLUSIONS	139
	REFERENCES	143
	VITAE	152



LIST OF TABLES

Table		Page
1	Treatments at Glasshouse Experiment.....	44
2	Application of Supplementary Fertilizers.....	45
3	Chemical Composition of PRs Used	49
4	Solubility of PRs in 2% Citric Acid	51
5	Solubility of PRs in 2% Formic Acid.....	51
6	Solubility of PRs in 2% Neutral Ammonium Citrate	51
7	Correlation Coefficient Between Solubility Test with P Uptake by Oil Palm Seedling 9 Months After PR Application	57
8	Soil Analysed Serdang Series	59
9	pH (H ₂ O) in the Soil Planted with Oil Palm Seedlings	60
10	pH (CaCl ₂) in the Soil Planted with Oil Palm Seedlings.....	61
11	Bray I P in the Soil Planted with Oil Palm Seedlings in Glasshouse Experiment	64
12	Olsen P in the Soil Planted with Oil Palm Seedlings in Glasshouse Experiment	65
13	Exchangeable K in the Soil Planted with Oil Palm Seedlings in Glasshouse Experiment	67
14	Exchangeable Mg in the Soil Planted with Oil Palm Seedlings in Glasshouse Experiment	69



15	Exchangeable Ca in the Soil Planted with Oil Palm Seedlings in Glasshouse Experiment	70
16	Diameter of Trunk of Oil Palm Seedlings in Glasshouse Experiment	72
17	Total Dry Matter Yield 9 Months after PR Application	74
18	Total Dry Matter Yield Analysed by Contrast Procedure.....	76
19	Plant P Uptake of 9 Months Old of Oil Palm Seedlings	79
20	Plant P Uptake Analysed by Contrast Procedure	82
21	Relative Agronomic Effectiveness of Various PRs Based on Dry Weight Production	84
22	Relative Agronomic Effectiveness of Various PRs Based on Plant P Uptake	85
23	pH (H₂O) in Incubation Study	93
24	pH (CaCl₂) in Incubation Study	94
25	Bray I Extractable P in Incubation Study	97
26	Olsen Extractable P in Incubation Study	98
27	Exchangeable K Incubation Study	101
28	Exchangeable Ca in Incubation Study	102
29	Exchangeable Mg in Incubation Study	104
30	PR Dissolution Based on Increased in Exchangeable Ca for Various Incubation Periods (%)	105
31	Soil Phosphorus Status Parameters at 1 Minute 1 month after PR Application	119



32	Soil Phosphorus Status Parameters at 40 Minutes 1 month after PR Application	120
33	Soil Phosphorus Status Parameters at 100 Minute 1 month after PR Application	121
34	Isotopically Exchangeable P at 1 minute (E1) 1 Month after PR Application	124
35	Size of P Pools in the Soil 1 Month after PR Application	126
36	Expected P Derived from Fertilizer (%Pdff) in the Soil 1 Month after PR Application	128
37	Experimental Parameters of Isotopically Exchangeable P at 3 Months after PR Application	129
38	Experimental Parameters of Isotopically Exchangeable P at 3 Months after PR Application	130
39	Experimental Parameters of Isotopically Exchangeable P at 3 Months after PR Application	131
40	Relative Agronomic Effectiveness of Various PRs 9 Months After PR Application	134
41	Correlation Coefficient between Isotopically Exchangeable P Values and P Uptake by Oil Palm Seedlings 9 months after PR Application	136
42	Correlation Coefficient Among Status and Kinetic Parameters of Isotopically Exchangeable P	137



LIST OF FIGURES

Figure		Page
1	Relationship between PRs Solubility in 2% Citric Acid (% of Rock) and CaO/P ₂ O ₅ (weight%)	53
2	Relationship between PRs Solubility in 2% Citric Acid (% of Total P ₂ O ₅) and CaO/P ₂ O ₅ (weight%)	53
3	Relationship between PRs Solubility in 2% Formic Acid (% of Rock) and CaO/P ₂ O ₅ (weight%)	54
4	Relationship between PRs Solubility in 2% Formic Acid (% of Total P ₂ O ₅) and CaO/P ₂ O ₅ (weight%)	54
5	Relationship between PRs Solubility in 2% NAC (% of Rock) and CaO/P ₂ O ₅ (weight%)	55
6	Relationship between PRs Solubility in 2% Citric Acid (% of Total P ₂ O ₅) and CaO/P ₂ O ₅ (weight%)	55
7	Relative Dry Matter Yield (%) of Oil Palm Seedlings versus P Rates	78
8	Relative P(%) of Oil Palm Seedlings versus P Rates	81
9	The Relationship between Plant P Uptake and E Value.....	133



LIST OF ABBREVIATIONS

2% CA	-	2% Citric Acid
2% FA	-	2% Formic Acid
NAC	-	Neutral Ammonium Citrate
TSP	-	Triple Sperphosphate
CIRP	-	Christmas Island Phosphate Rock
NCPR	-	North Carolina Phosphate Rock
JPR	-	Jordanian Phosphate Rock
APR	-	Algerian Phosphate Rock
CPR	-	China Phosphate Rock
TPR	-	Tunisia Phosphate Rock
OPRS	-	Oil Palm Research Station
Cf	-	Capacity Factor
Cp	-	Water Soluble P (Intensity Factor)
DMRT	-	Duncan's Multiple Range Test
E (t)	-	Isotopically Exchangeable Phosphorus at Time t
E1	-	Isotopically Exchangeable Phosphorus at 1 Minute
LSC	-	Liquid Scintillation Counter
n	-	Power Function Describing E(t)



Pdff	-	Phosphorus Derived from Fertilizer
PR	-	Phosphate Rock
PRs	-	Phosphate Rocks
r/R	-	Radioactivity in the Solution after Specific Time
R	-	Initial Radioactivity
RAE	-	Relative Agronomic Effectiveness
SA	-	Specific Activity
AAS	-	Atomic Absorption Spectrophotometer

**Abstract of the Thesis submitted to the Senate of Universiti Putra Malaysia
in Fulfillment of the Requirements for the Degree of Master of Agricultural
Science.**

**COMPARATIVE EFFICACY OF VARIOUS SOURCES
AND RATES OF PHOSPHATE ROCKS
TO OIL PALM SEEDLINGS**

By

MUHAMMAD EDWIN SYAHPUTRA LUBIS

June 1997

Chairman : Associate Prof. Dr. Zaharah A. Rahman

Faculty : Agriculture

Phosphate Rocks (PR) from various geographical locations are being imported into the Malaysian market mainly from Algeria, North Carolina (USA), Tunisia, China etc. PR vary widely in their physical, chemical and mineralogical properties. Consequently, the solubility and agronomic effectiveness of PR sources also vary widely. In addition, the agronomic effectiveness of PR depends on interactions between several factors, particularly PR material characteristics, soil properties, crop characteristics, and



environmental conditions. Hence, There is a need to evaluate the efficacy of various sources of PR as phosphate source for plant growth. In view of this, a glasshouse experiment using oil palm seedlings and a laboratory incubation experiment were used to evaluate the efficacies of these sources of PR. The study was undertaken with the following objectives :

1. to assess the solubility of PR in soil by various solubility tests.
2. to evaluate the dissolution of PR sources in an acid Malaysian soil, using an incubation experiment.
3. to determine the relative agronomic effectiveness of PRs to oil palm seedlings in glasshouse experiment.
4. to characterize the immediate and residual availability of PR using the E-value approach.

The solubility test showed that the neutral ammonium citrate (NAC) method gave more consistent results and was highly correlated with P uptake compared to 2 % formic acid and 2 % citric acid solubility tests. The solubility value as expressed by % of rock, gave higher coefficient correlation than the solubility value as expressed by % of total P_2O_5 . Based on neutral ammonium citrate solubility test, the rankings were : TSP > NCPR > APR > TPR > JPR >

CIPR > CPR. The correlation coefficient between solubility test and plant P uptake was almost constant with increasing rate of P applied.

Based on the glasshouse study using oil palm seedlings, TSP prove to be superior in promoting P uptake. The relative agronomic effectiveness (RAE) data for dry weight gave a similar trend to that for P uptake. In general amongst the PRs tested, the ranking of RAE can be classified separated into three categories, i.e : high (NCPR and APR), medium (TPR and JPR) and low reactivity (CIPR and CPR),.

The incubation study showed that the addition of PRs can improve some soil chemical characteristics. In this study it was observed that PRs improved soil pH, Exchangeable Ca and extractable P. The extent of PR dissolution increased with increasing incubation period. The percent dissolution of PR was much higher at lower level of PR application.

The E-value determinations showed that the ability of PR in providing available P in the soil depend on their reactivity. On the whole the ranking of reactivity from this study is in order of : NCPR>TPR>APR>JPR>CPR>CIPR. A good correlation was also observed between P uptake and E-values at 1 minute, and P in concentration in soil-water suspension (Cp)

Furthermore, it was observed that the highly reactive PR (NCPR, APR and TPR) were always ranked higher than the ones with low reactivity (CIPR and CPR) for all methods tested. The E-value method is a better method since the isotopic exchange technique provides the most complete analysis of soil available phosphate. It can assess the immediate and residual availability of P, determine the relative agronomic efficiency (RAE) of P fertilizers and calculate the P derived from fertilizer (%Pdff). The E-value method is a good method to estimate soil P fixing capacity without the need for conducting field or glasshouse experiments. It also has an advantage over chemical extractants because it does not disturb the soil components.



**Abstrak Tesis yang Dikemukakan Kepada Senat Universiti Putra Malaysia
Sebagai Memenuhi Syarat Keperluan Untuk Ijazah Master.**

**PERBANDINGAN KECEKAPAN AGRONOMIK PELBAGAI
JENIS BATUAN FOSFAT DAN KADAR PEMBERIANNYA
PADA ANAK POKOK KELAPA SAWIT**

Oleh

MUHAMMAD EDWIN SYAHPUTRA LUBIS

Jun 1997

Pengerusi : Prof. Madya Dr. Zaharah Abd. Rahman

Fakulti : Pertanian

Dewasa ini, Malaysia mengimport pelbagai jenis batuan fosfat yang didapati dari pelbagai lokasi seperti batuan fosfat dari Tunisia, Algeria, North Carolina, China dan lain-lain. Setiap jenis batuan fosfat mempunyai ciri-ciri fizikal, kimia dan mineralogi yang berbeza diantara satu sama lain. Ini menyebabkan kelarutan dan keberkesanan agronomik sesuatu batuan fosfat berbeza-beza. Kecekapan agronomik batuan fosfat adalah bergantung kepada beberapa faktor seperti ciri-ciri batuan fosfat itu sendiri, sifat-sifat tanah, jenis



tanaman dan keadaan persekitaran. Untuk tujuan ini, kajian di makmal dan kajian di rumah kaca yang menggunakan anak benih kelapa sawit telah dijalankan untuk menilai kecekapan agronomik beberapa jenis batuan fosfat. Selaras dengan itu tujuan kajian ini dijalankan adalah :

1. Untuk menilai kelarutan pelbagai batuan fosfat di dalam tanah dengan menggunakan beberapa ujian kelarutan tak langsung.
2. Untuk menilai kelarutan pelbagai batuan fosfat di dalam tanah berasid berdasarkan kajian inkubasi.
3. Untuk mengetahui kecekapan agronomik pelbagai batuan fosfat berdasarkan kajian di rumah kaca dengan menggunakan anak benih kelapa sawit.
4. Untuk mencirikan kebolehdapatan segera dan sisa baki P di dalam tanah dengan melibatkan percubaan kinetik penukaran isotopik.

Ujian kelarutan tak langsung yang telah dijalankan menunjukkan larutan ammonium sitrat neutral memberikan nilai korelasi yang positif dan tinggi dengan pengambilan P oleh anak pokok kelapa sawit jika dibandingkan dengan ujian 2% asid formik dan 2% asid sitrik. Nilai kelarutan yang dikira berdasarkan

peratusan batuan membenkan korelasi koefisien yang lebih baik jika dibandingkan dengan nilai kelarutan yang dikira berdasarkan peratusan jumlah P_2O_5 . Berdasarkan kelarutan di dalam larutan ammonium sitrat neutral, keputusan yang didapati adalah :

$$TSP > BFNC > BFA > BFT > BFJ > BFPK > BFC.$$

Koefisien korelasi diantara ujian kelarutan tak langsung dengan pengambilan P oleh anak pokok kelapa sawit adalah menunjukkan kostant dengan pertambahan kadar pemberian P di dalam tanah.

Berdasarkan kajian yang dijalankan di rumah kaca, pengambilan P yang paling tinggi adalah pada rawatan TSP. Kecekapan agronomik berdasarkan berat kering membenkan keputusan yang sama dengan kecekapan agronomik berdasarkan pengambilan P oleh tanaman. Pada amnya kecekapan agronomik boleh dibahagikan kepada tiga kategori iaitu : tinggi (BFNC dan BFA), sederhana (BFT dan BFJ) dan rendah (BFPK dan BFC),

Kajian inkubasi menunjukkan pemberian fosfat boleh meningkatkan beberapa ciri tanah. Pemberian batuan fosfat dapat meningkatkan pH tanah, tukarganti Ca dan P terekstrak. Kadar kelarutan batuan fosfat meningkat dengan

pertambahan masa inkubasi dan peratusan pelarutan batuan fosfat adalah lebih tinggi pada paras pemberian batuan fosfat yang rendah.

Kaedah kinetik penukaran isotop yang dilakukan di dalam makmal mendapati bahawa keupayaan batuan fosfat untuk membekalkan P tersedia di dalam tanah adalah bergantung kepada kereaktifan batuan tersebut. Keputusan kajian ini, menunjukkan susunan kereaktifan adalah seperti : BFNC, BFT, BFA, BFJ, BFC dan BFPK. Kajian ini juga memberikan nilai korelasi yang positif dan tinggi dengan pengambilan P oleh anak pokok kelapa sawit.

Keputusan keseluruhan kajian menunjukkan BFNC, BFA, BFT, BFJ mempunyai kereaktifan yang paling tinggi dibandingkan dengan BFC dan BFPK dengan menggunakan apa ujian sekalipun. Secara am, kesemua kaedah yang digunakan memberikan keputusan yang sama. Oleh itu kaedah isotop adalah kaedah yang lebih baik, kerana kaedah ini boleh memberikan kebolehdapatan segera dan sisa baki P di dalam tanah, menentukan kecekapan agronomik, penentuan P yang didapati dari baja dan kaedah ini juga boleh menentukan keupayaan pengikatan P oleh tanah tanpa perlu menjalankan kajian di rumah kaca atau di ladang. Kaedah ini juga lebih baik jika dibandingkan dengan menggunakan larutan pengecitraan kerana kaedah ini tidak mengganggu komponen tanah.

CHAPTER 1

INTRODUCTION

Phosphorus deficiency can be a major factor in declining crop production in many acidic agriculture soils in developing countries (Chien, 1995; Chien and Menon, 1995). In acid soils of the tropics, including Malaysia, P availability is one of the major limiting factors in crop production, because most of the soils are inherently low in P due to the presence of oxides and hydroxides of Fe and Al that fix large amounts of applied P fertilizer (Owen, 1953; Puspharajah et al., 1977; Kalpage and Wong, 1978; Zaharah, 1979). Therefore, application of phosphate fertilizers is required for them to be highly productive.

It has been shown that direct application of phosphate rock (PR) may be an agronomically and economically attractive alternative to the use of the more expensive soluble P fertilizers (Khasawneh and Doll, 1978; Hammond et al., 1986; Chien et al., 1990; Chien and Friesen, 1992; Sale and Mokwunye, 1993).



Numerous studies have shown that direct application of PR is especially favourable for the plantation crops, e.g., oil palm, rubber, coconut and tea (Ling et al., 1990; Pushparajah et al., 1990).

Several studies have also shown that phosphorus is a major plant nutrient for proper growth and production in oil palm (Zakaria et al., 1990; Fong and Sofi, 1993; Fong, 1993) because many of the vital growth processes in oil palm are associated with the phosphorus element, for instance nucleic acids which govern the process of cell development as well as affect fruit ripening. In addition, an adequate presence of this element is necessary for the efficient use and action of nitrogen (Turner and Gillbanks, 1974 ; Adiwiganda and Siahaan, 1994). One of the cheapest source of P for oil palm is phosphate rock (PR). In acidic soils of the humid tropics, PR was found to be as efficient as the more soluble phosphate in term of yield response of oil palm (Chan, 1981). The residual effect of PR was found to be significant in acid soils for at least two to four years (Chan, 1981).

Malaysia has been using PR from Christmas Island (CIPR) since the 1930's, but recently, PR from various geographical locations are being imported into the Malaysian market. This includes PR from Jordan, North Carolina, Tunisia, China etc. PR vary widely in their physical, chemical and mineralogical

properties (Lehr and McClellan, 1972; Chien, 1995). Consequently, the solubility and agronomic effectiveness of PR sources also vary widely (Chien, 1995 ; Sale and Mokwunye, 1993). In addition the agronomic effectiveness of phosphate rocks depend on interactions between several factors, particularly PR mineralogical properties, soil properties, crop characteristics, and environmental conditions (Khasawneh and Doll, 1978 ; Hammond et al., 1986).

Hence, there is a need to evaluate the efficacy of various sources of PR as a phosphate source for plant growth. The usual method of investigation involve field trials to evaluate biological responses to an application of various forms of P fertilizers. But field experiments are generally time consuming and expensive. In view of this, a glasshouse experiment using oil palm seedlings and a laboratory experiment will be used to evaluate the efficacy of various sources of phosphate rocks.

Thus, the study was undertaken with the following objectives :

- ◆ To Assess the solubility of PR in the soil by using various indirect solubility test.

- ◆ To assess the dissolution of PR sources in an acid Malaysian soil, using incubation experiment.

- ◆ To evaluate the efficacy of the various sources of phosphate rocks versus TSP to oil palm seedlings

- ◆ Quantification of P uptake from various phosphate rocks in oil palm seedlings

- ◆ Investigating the interaction between sources and rates of application of phosphate rocks to oil palm seedlings.

- ◆ To assess the immediate and residual availability of P by the E value approach.